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Biscontini et al.

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(54) **ANTENNA DEVICE FOR A BASE STATION ANTENNA SYSTEM**

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H01Q 9/26 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/246*** (2013.01); ***H01Q 9/26*** (2013.01); ***H01Q 9/285*** (2013.01); ***H01Q 21/26*** (2013.01); ***H01Q 25/001*** (2013.01)

(58) **Field of Classification Search**
CPC H01Q 1/246; H01Q 25/001; H01Q 21/26; H01Q 9/26; H01Q 9/285
(Continued)

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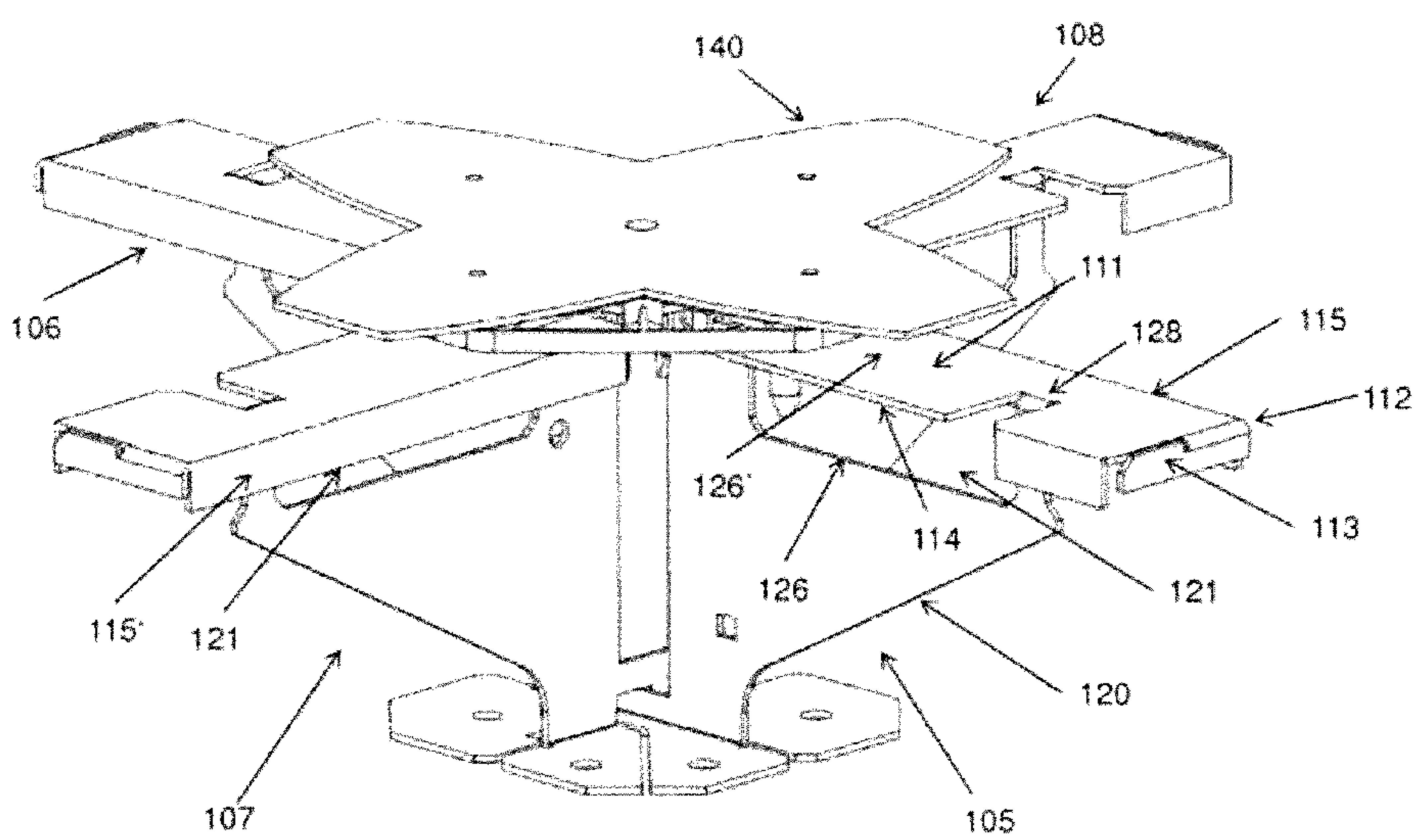
(57) **ABSTRACT**

An antenna device is described. The antenna device **100** comprises at least two antenna elements each of comprising a first radiating element **110** and a corresponding second radiating element **120**. The second radiating element **120** extends in a height direction along a common center axis A from a foot of the antenna device **100** to its corresponding first radiating element **110**. The first radiating element **110** extends in a length direction outwards from the common center axis A. The length of the first radiating element **110** defines the maximum supported wavelength. Furthermore, each first radiating element **110** has a greater length than its width and each first radiating element **110** is electrically coupled to its corresponding second radiating element **120** along the length direction, so that the second radiating element **120** can contribute to the smaller wavelengths.

14 Claims, 15 Drawing Sheets



(51) **Int. Cl.**

H01Q 9/28	(2006.01)
H01Q 21/26	(2006.01)
H01Q 25/00	(2006.01)

(58) **Field of Classification Search**
USPC 343/797, 798, 806
See application file for complete search history.

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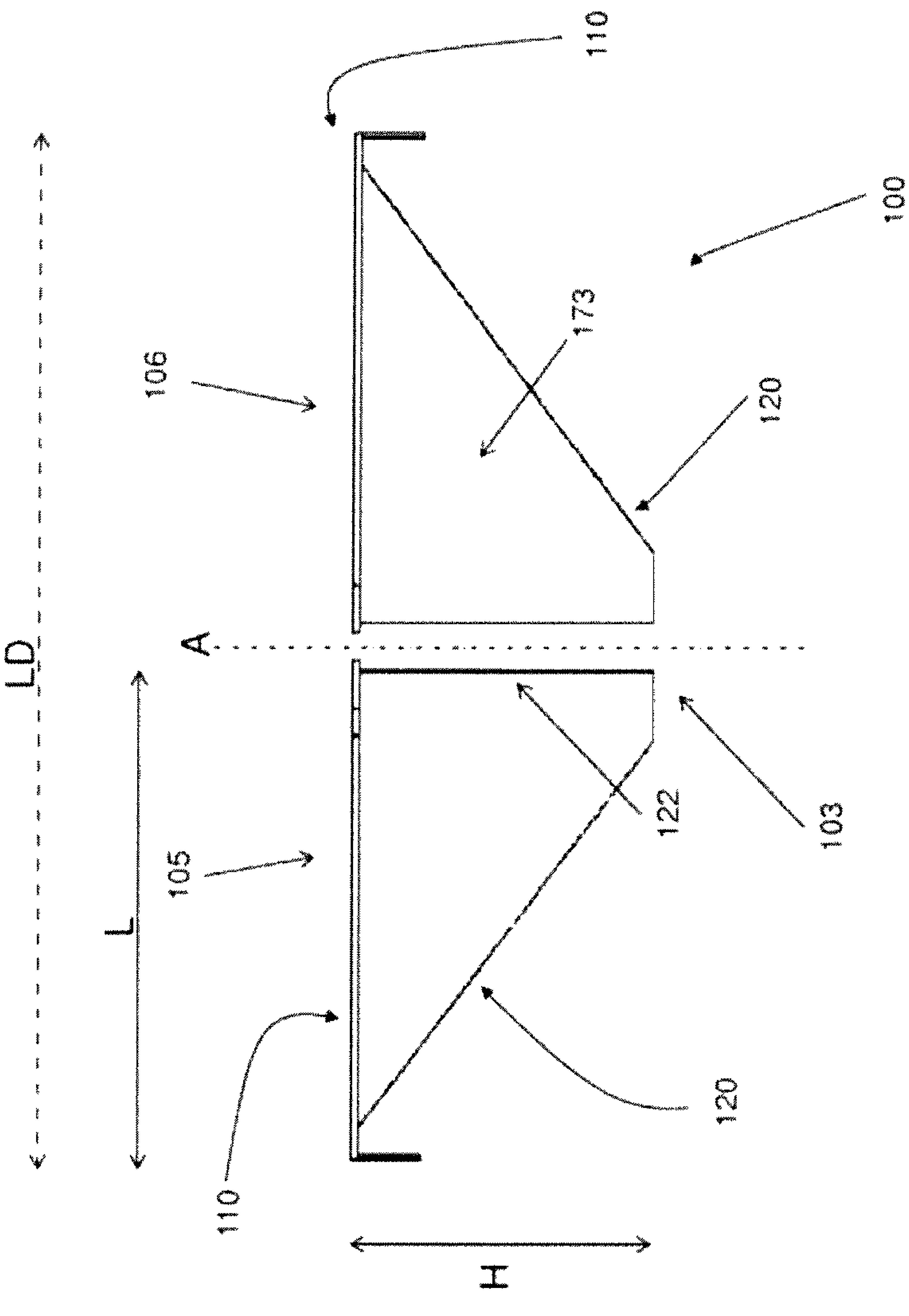


FIG. 1

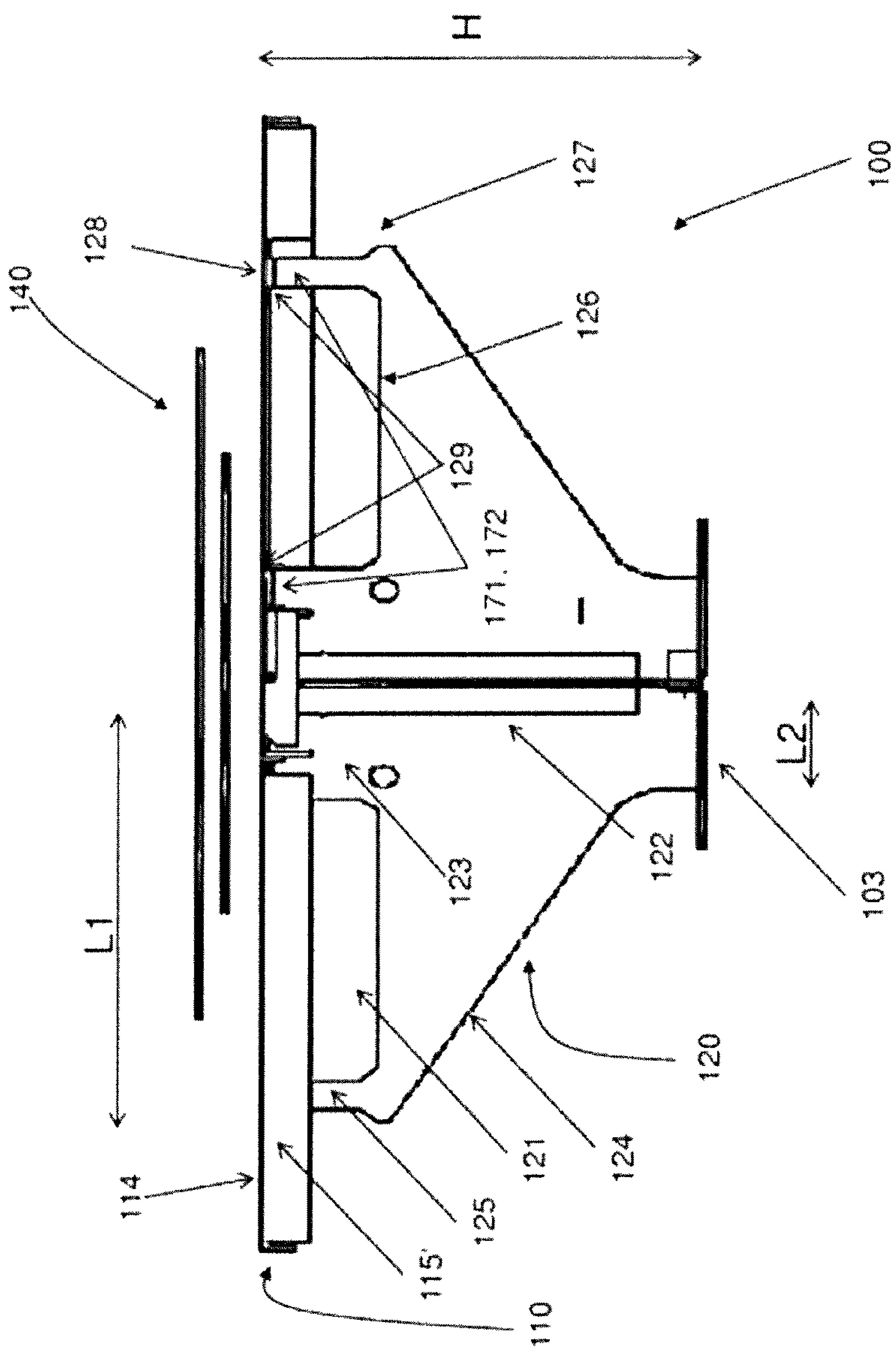

H
127
100
128
140
126
129
171, 172
O
I
L1
L2
123
122
103
120
121
124
125
114
115'
110

FIG. 2

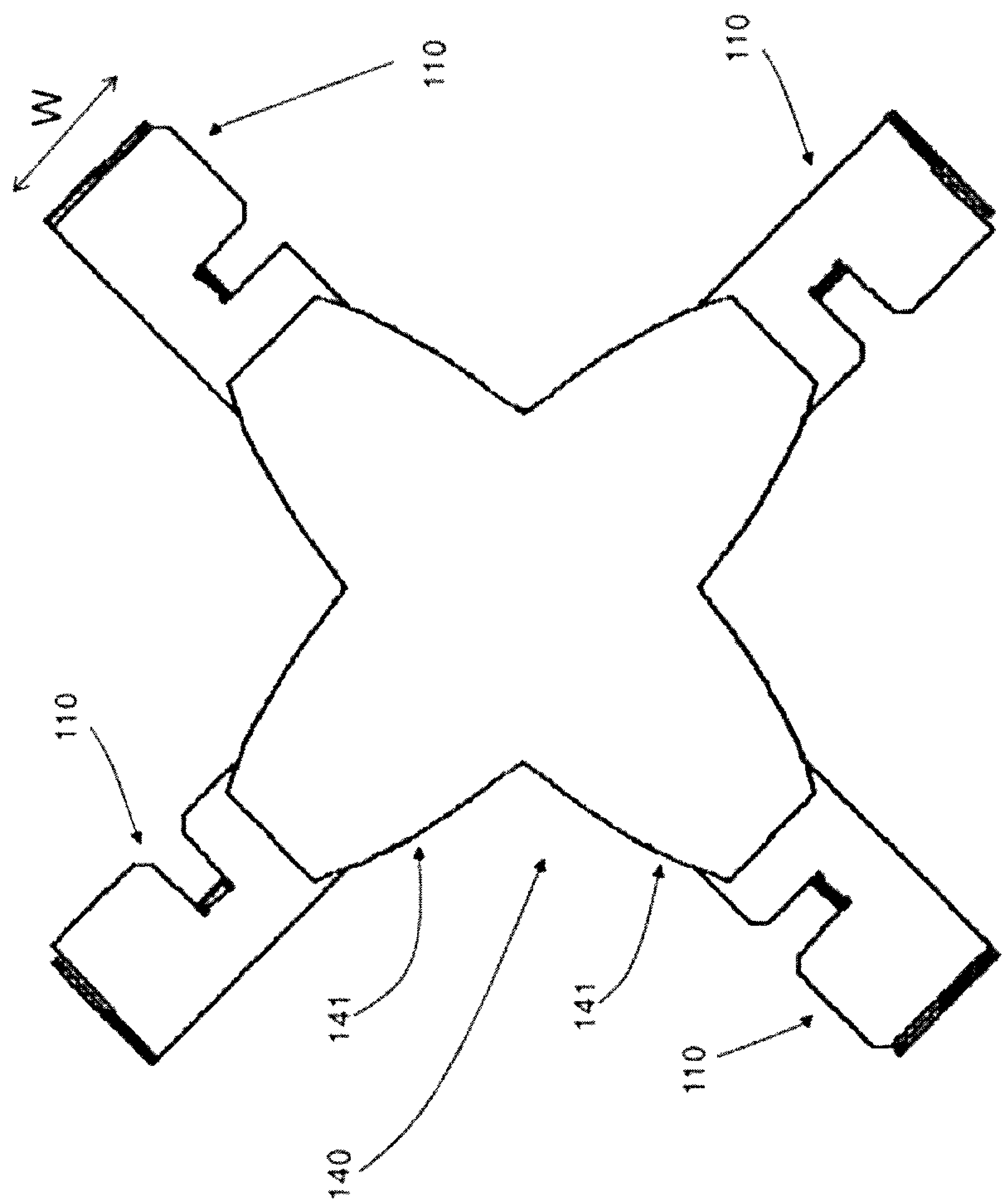
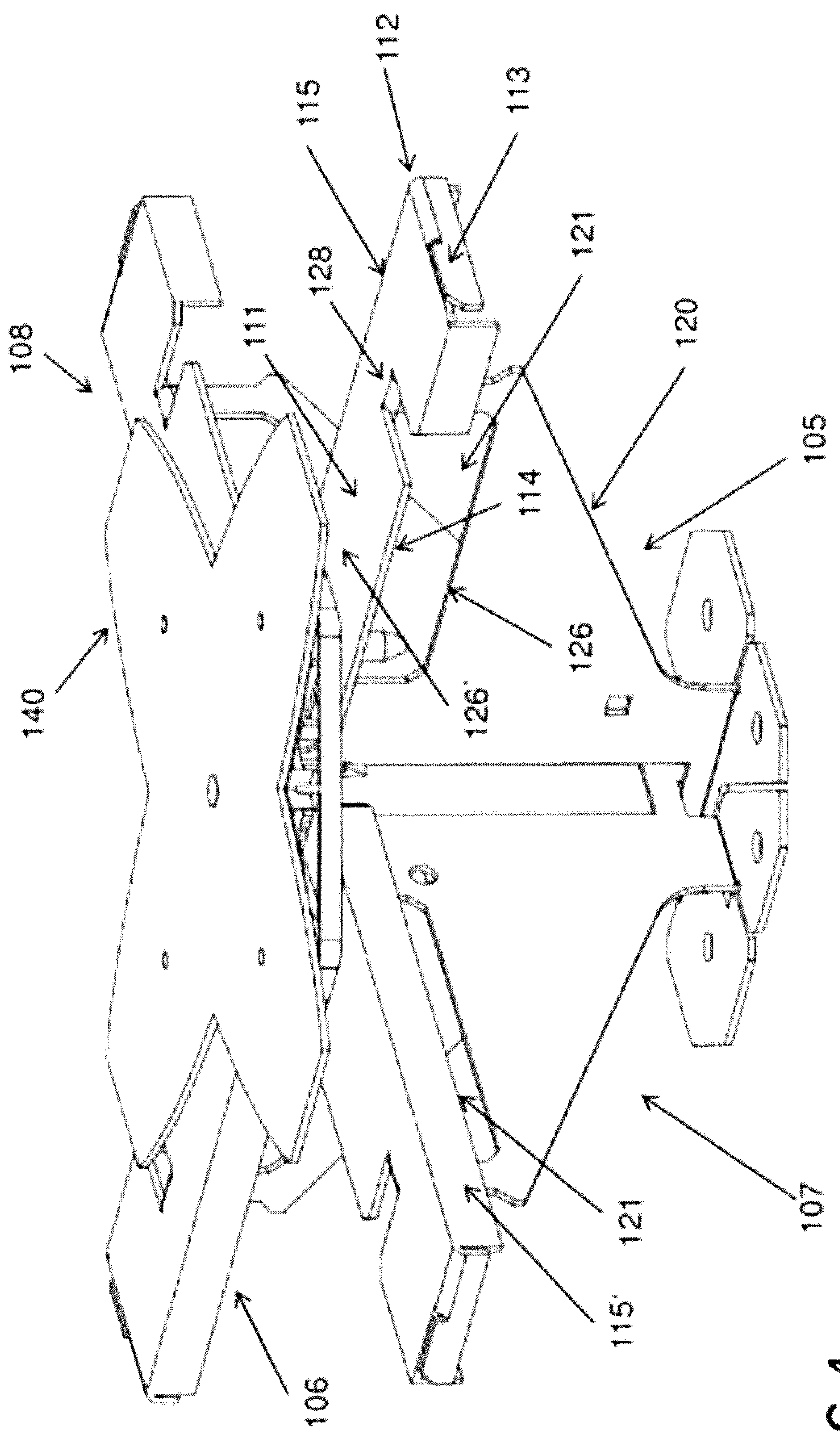


FIG. 3



112
113
115
128
121
111
108
120
105
114
126
126'
140
121
107
115'
106

FIG. 4

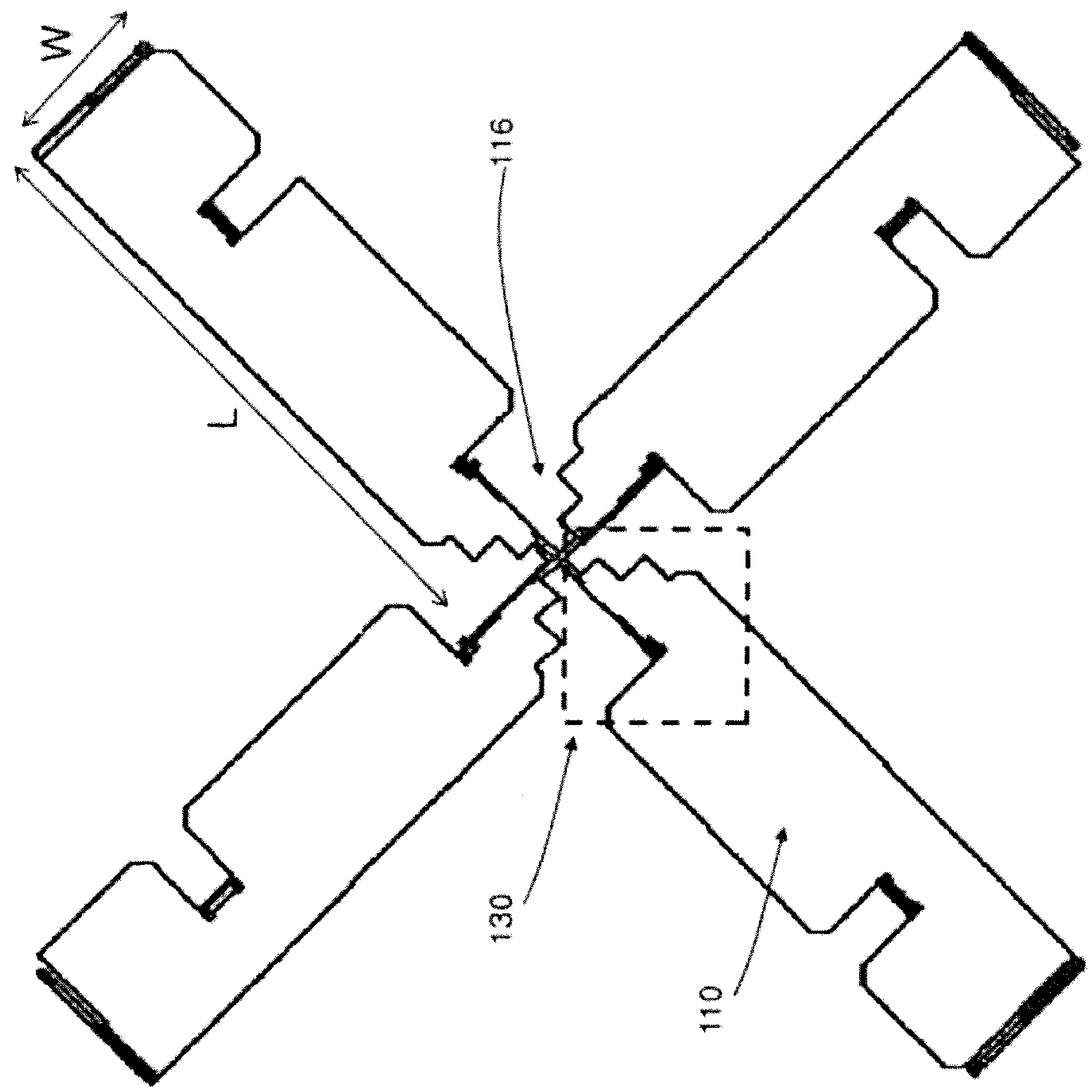


FIG. 5

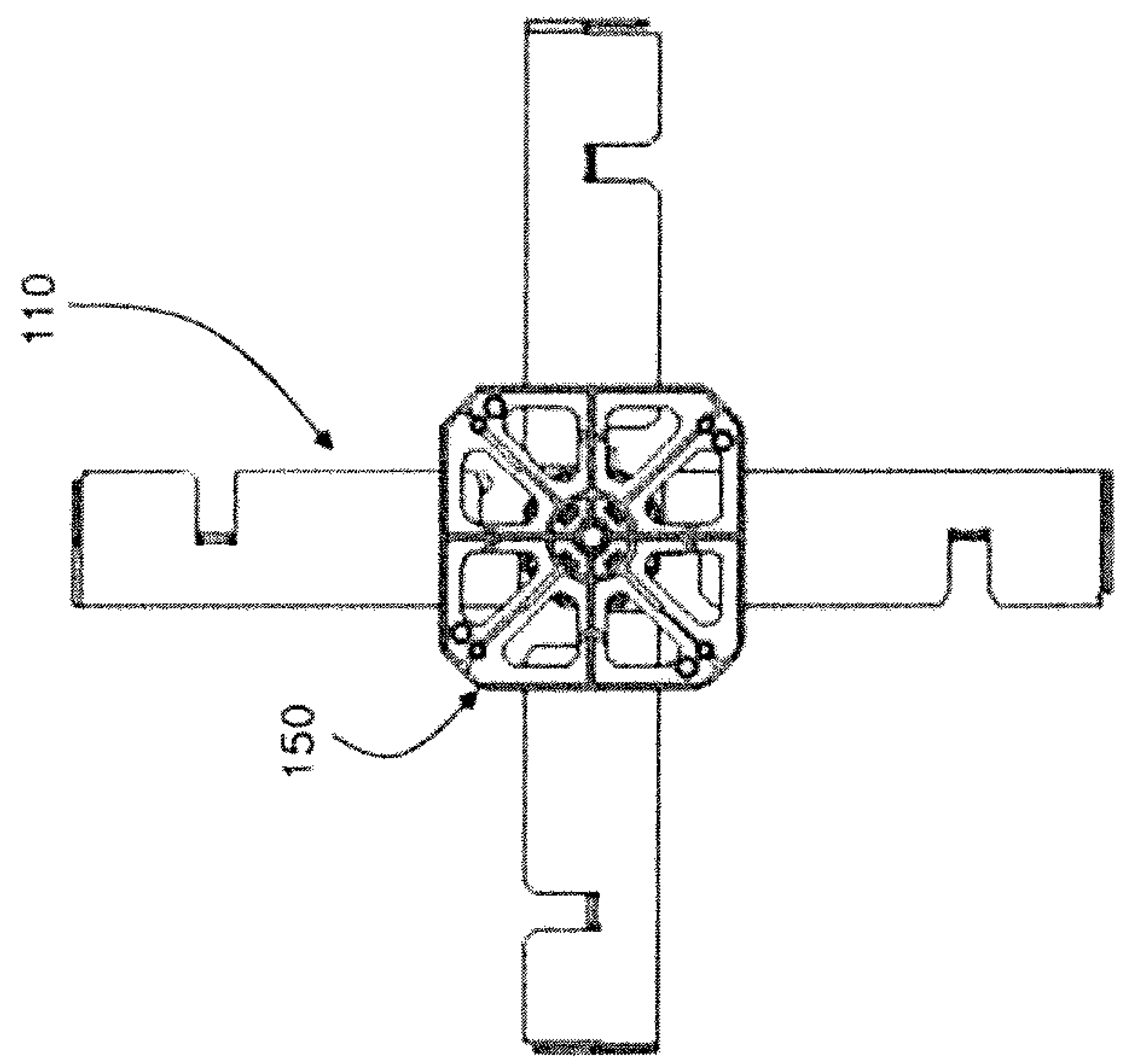


FIG. 6

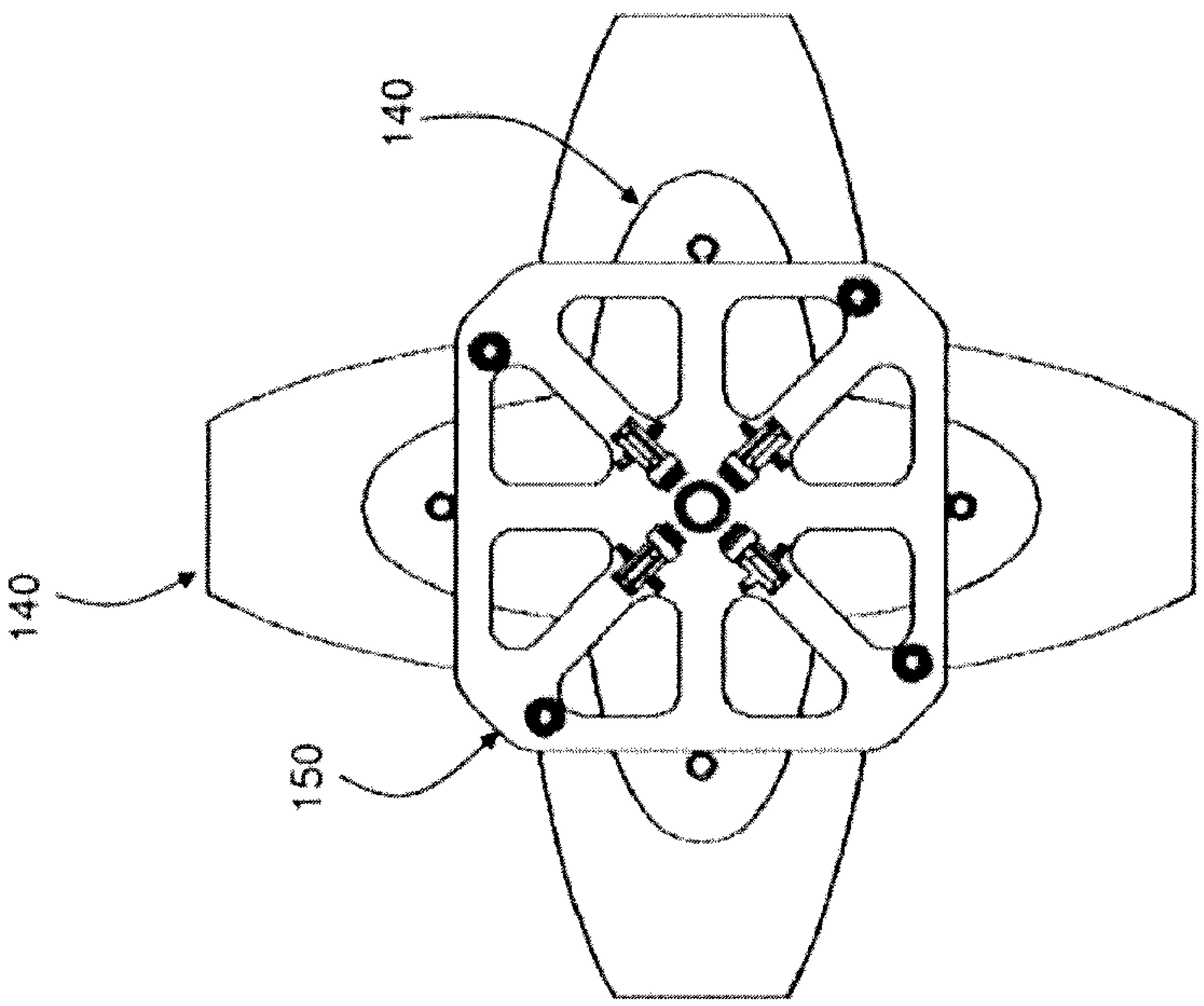


FIG. 7

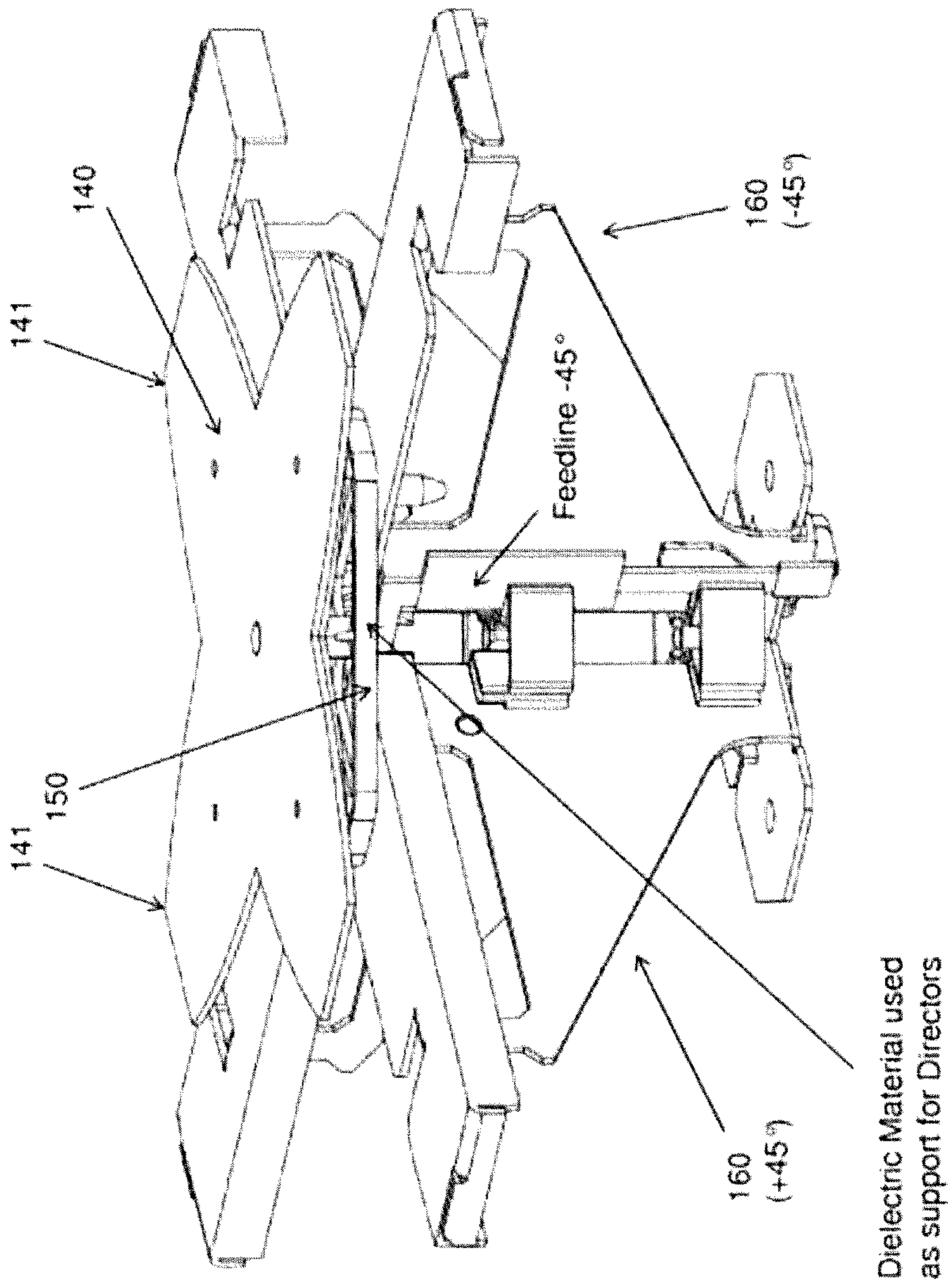

141
140
141
150
Feedline -45°
160
(-45°)
160
(+45°)
Dielectric Material used
as support for Directors

FIG. 8

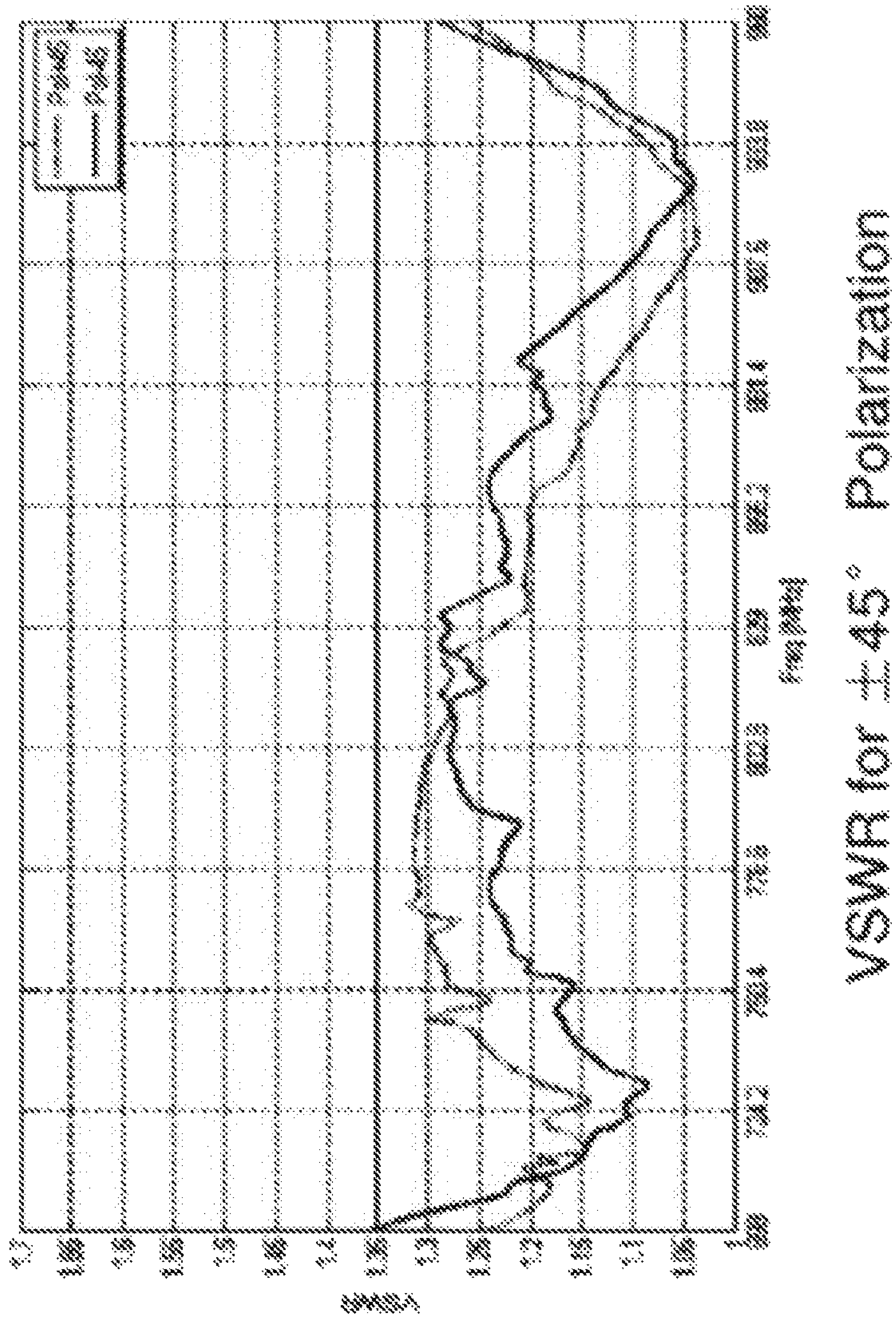


FIG. 9

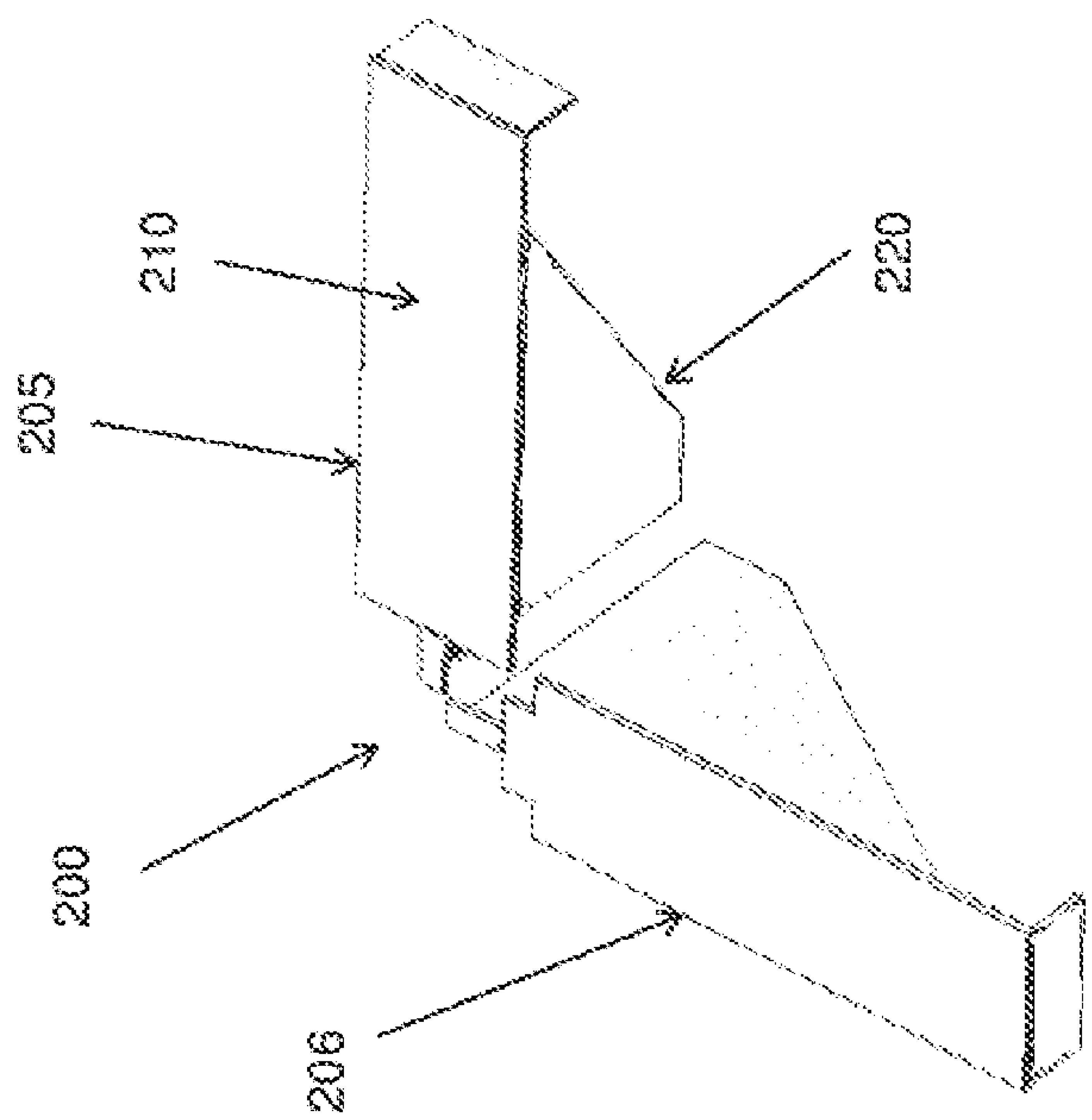


FIG. 10

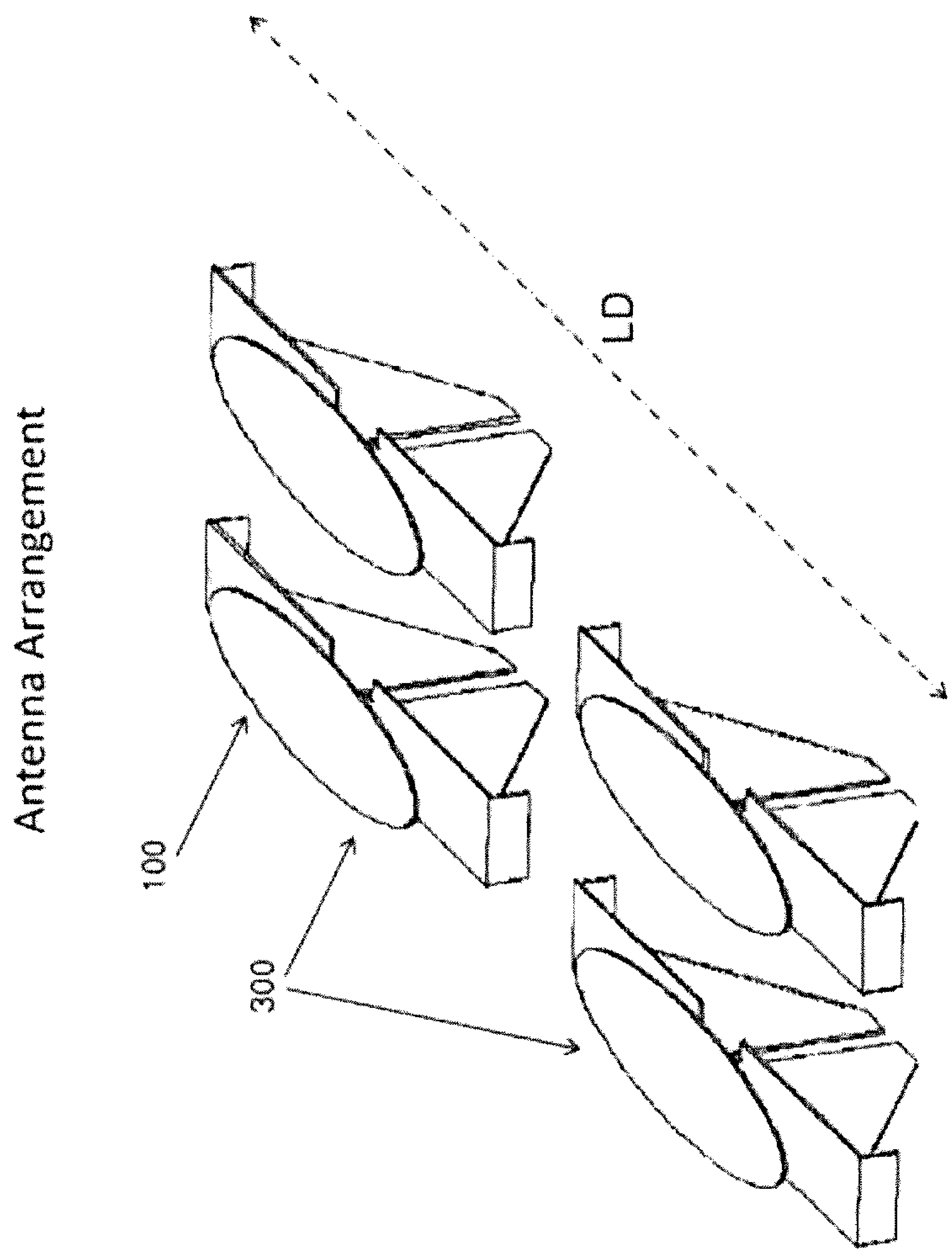


FIG. 11

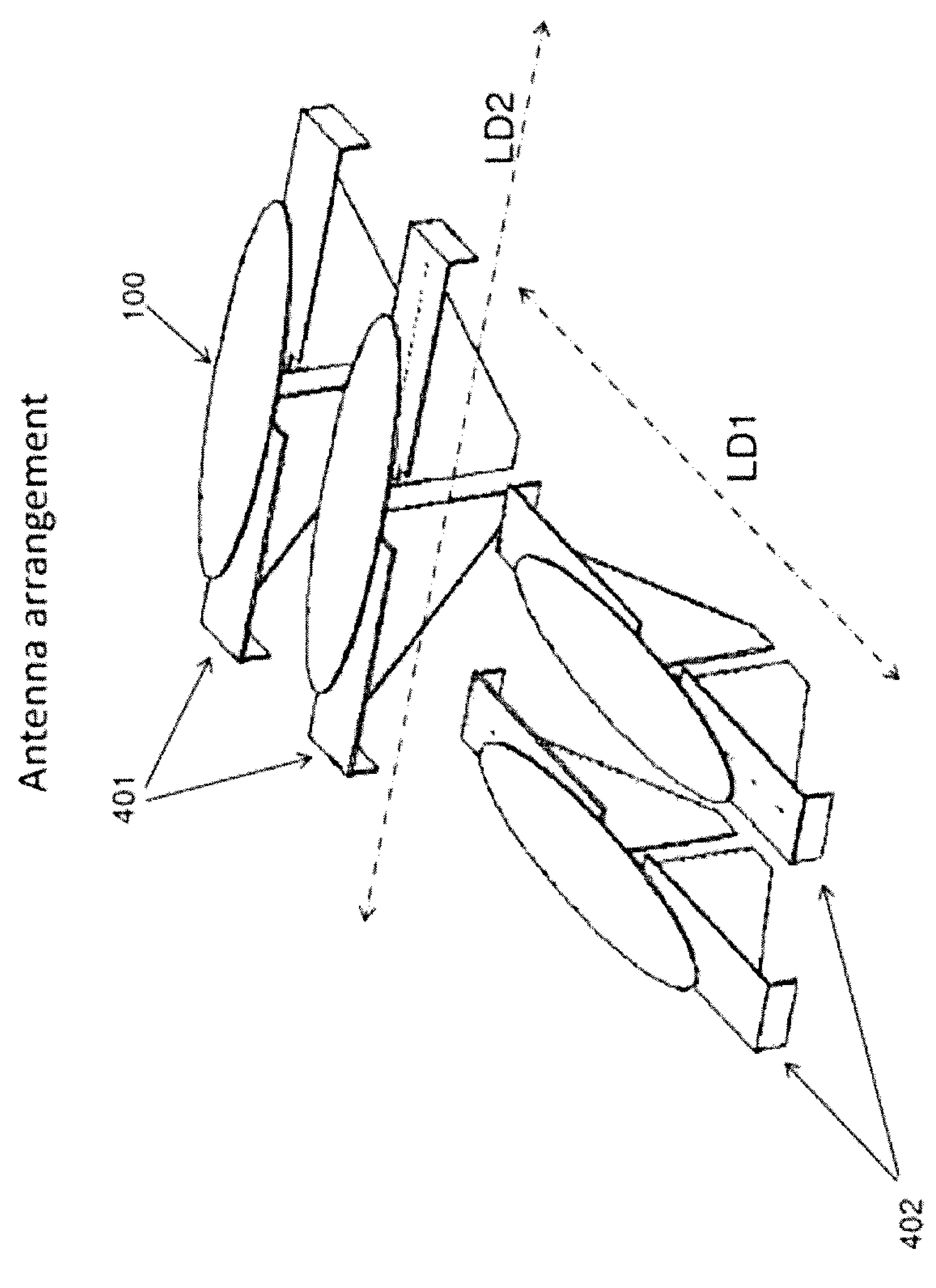


FIG. 12

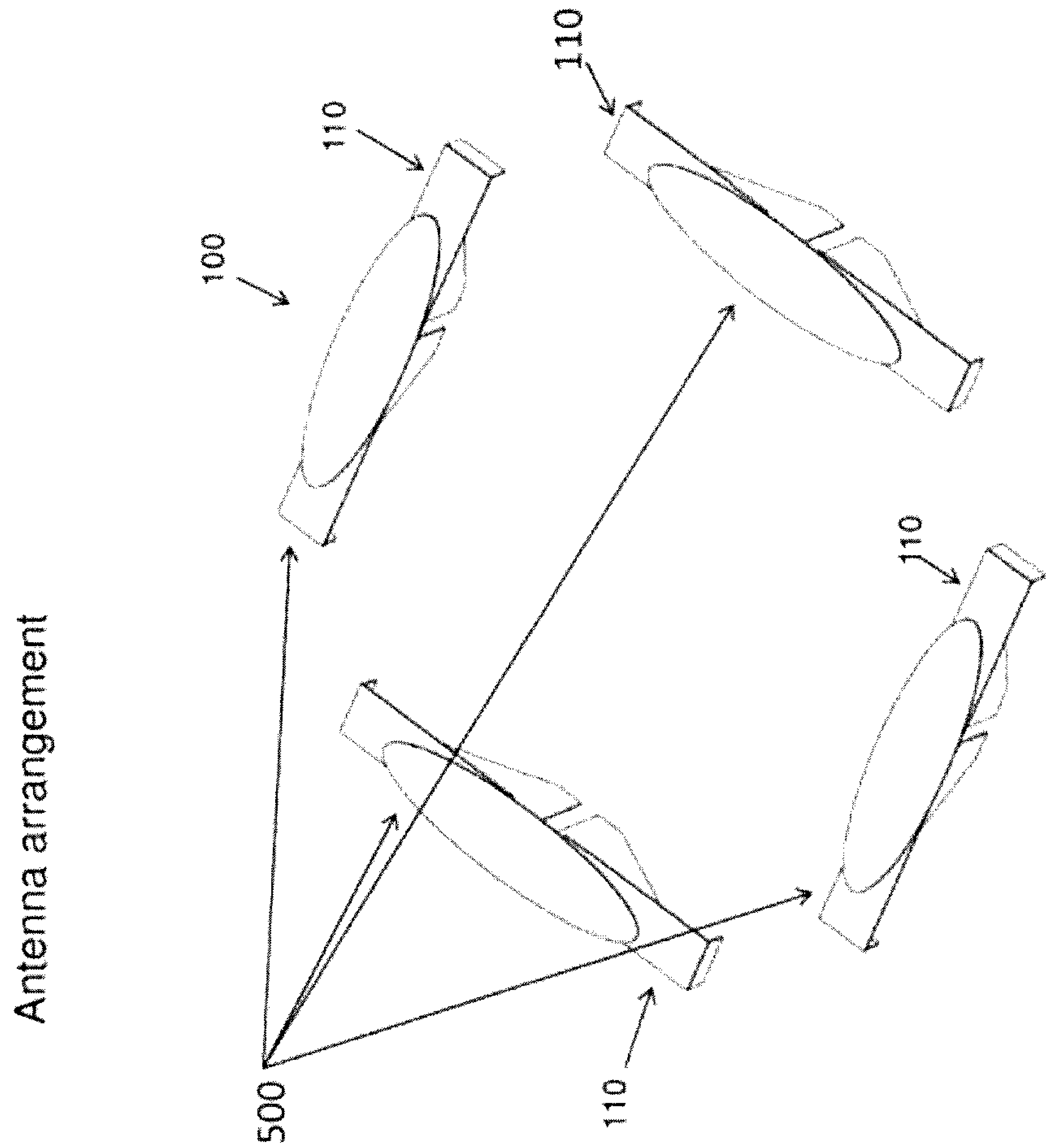


FIG. 13

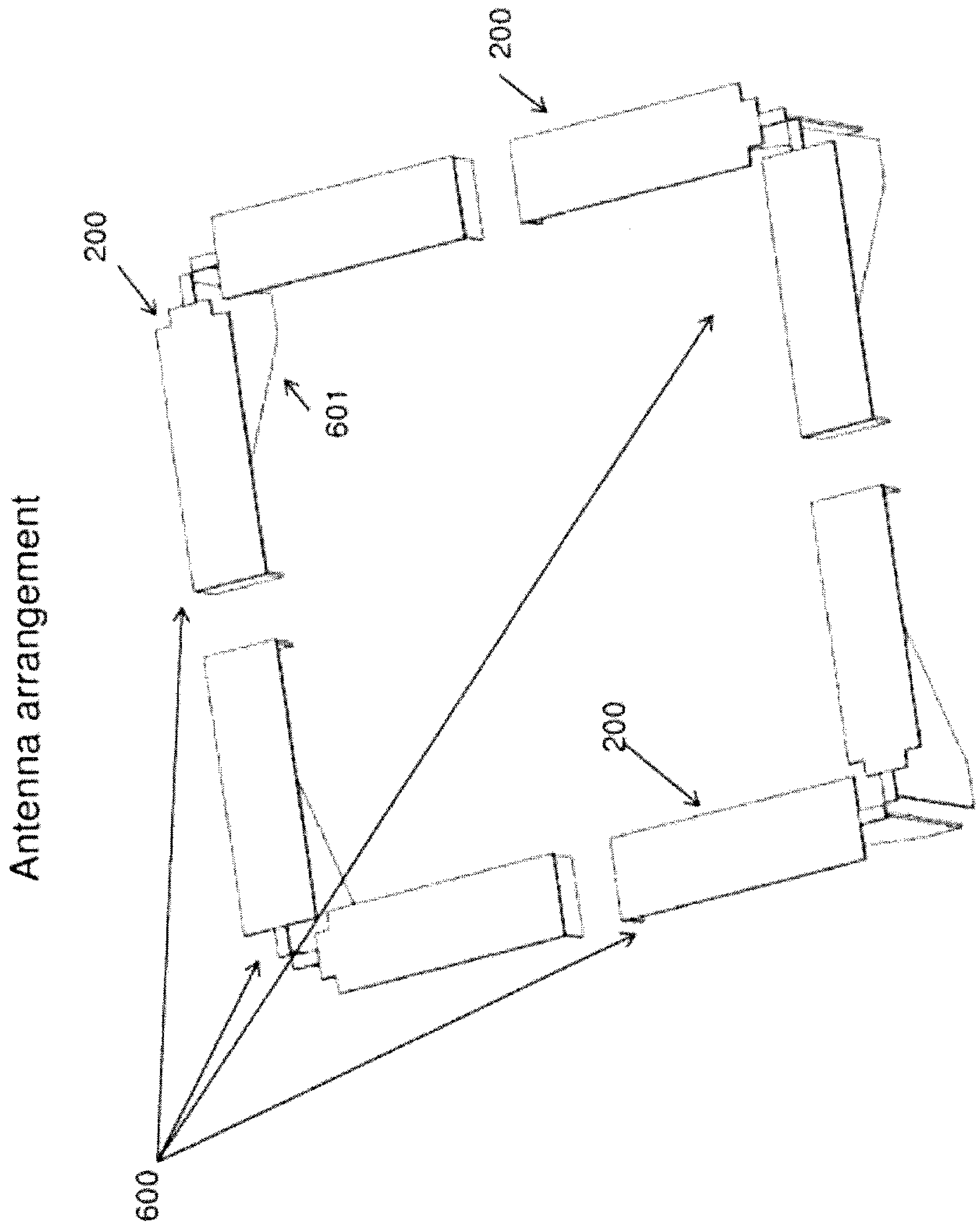


FIG. 14

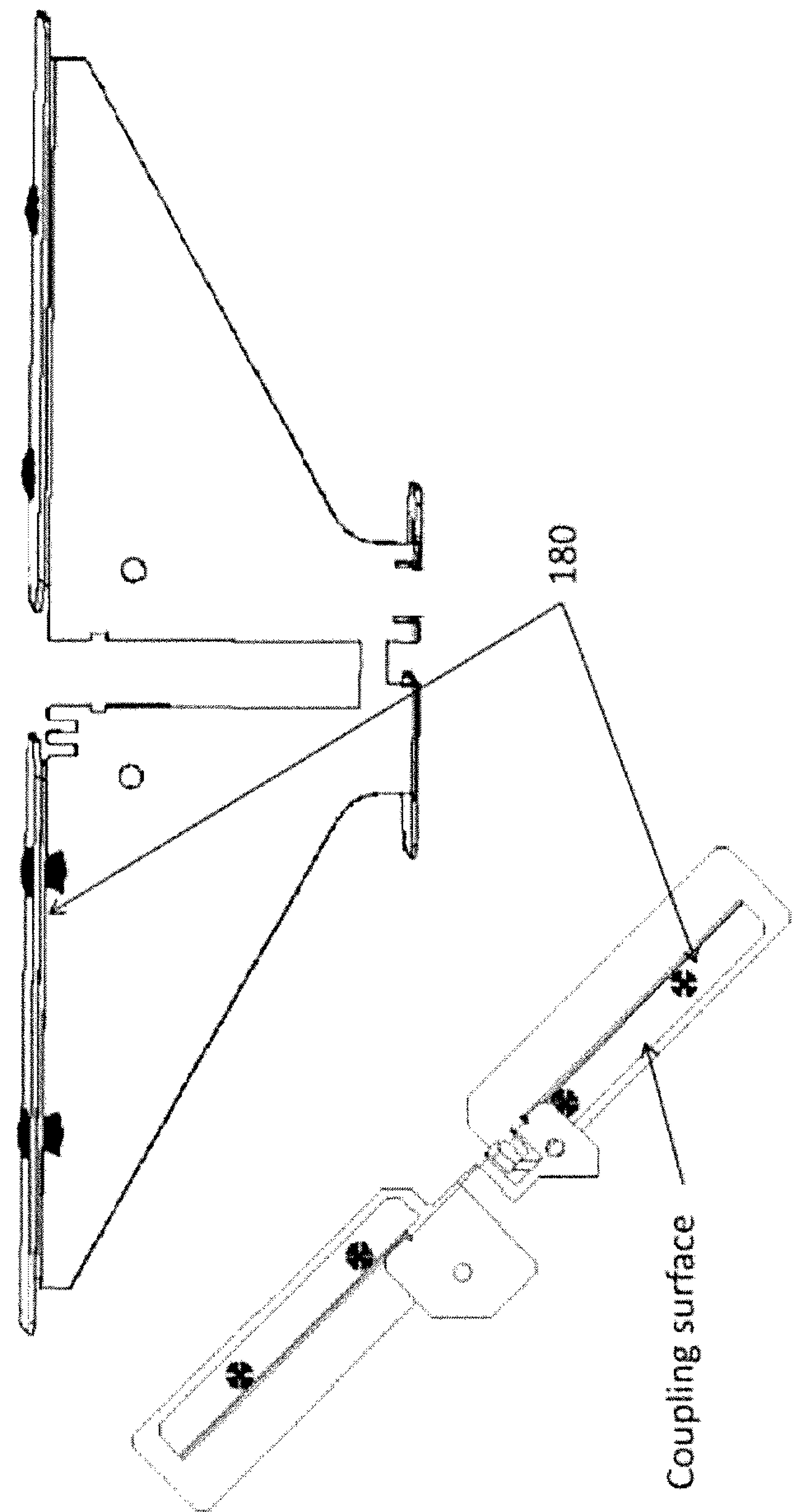


FIG. 15

ANTENNA DEVICE FOR A BASE STATION ANTENNA SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/EP2014/072897, filed on Oct. 24, 2014, the disclosure of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present application relates to an antenna device for a base station antenna system.

BACKGROUND

The continuous increase of data-traffic demand challenges and drives the mobile telecommunication industry to introduce new frequency bands, standards and radio access technologies e.g. MIMO, beamforming etc. From an antenna point of view that means multiple antenna systems which offer more agile beam possibilities. In order to achieve more agile beam antennas, phase and amplitude have to be set in real time and in a flexible way. This leads to so called Active Antenna Systems, AAS, which means integrating radio transceiver units, RRU, with base station antenna systems. This integration leads to highly complex systems and strongly influences the antenna form factor which is fundamental for commercial field deployment. Replacing traditional antennas with AAS or simply obtaining new site permissions if the form factor of the antenna is not similar to traditional antennas is a time consuming and hard task to be fulfilled for the operators, and this is also valid for traditional passive base station antenna systems.

As it is well known, ultra broad band base station antenna systems typically operate in the 698-960 MHz ("Low Band") and 1.7-2.7 GHz ("High Band") spectrum which includes most cellular network frequency bands used today. A relative bandwidth of the ultra broad band base station antenna systems can be calculated by the equation:

$$\text{The relative bandwidth}=2^*(f\text{max}-f\text{min})/(f\text{max}+f\text{min}),$$

and is supposed to be greater than 30%.

On the one hand, a base station antenna element must have a sufficient depth for supporting the lowest frequency of the cellular network frequency bands and achieving a relative bandwidth which is greater than 30%. In the meanwhile, with the growing demand for a deeper integration of antennas with Radios, as e.g. in AAS, it is very important to reduce the dimensions of ultra broad band antennas without compromising the antenna's key performance.

In view of the above, one of the dominant limiting technological factors for reducing the overall antenna dimensions is the height of the lower band radiating element which strongly influences the overall antenna depth. Significantly reducing the antenna height means to strongly simplify the overall deploying process of AAS and traditional passive antenna systems.

Conventional base station antennas, do not present any solutions for reducing the lower frequency antenna element depth during supporting the lowest frequency of the cellular network frequency bands and achieving a relative bandwidth which is greater than 30%.

SUMMARY

In view of the above-mentioned disadvantages and problems, the present application aims to improve the state of the art. In particular, the object of the present application is to provide an antenna device, which provides a better compromise between a size of the antenna device and an achievable bandwidth of the antenna device. The present application also intends to enable a simple manufacture of the dipole of the antenna device. The present application also aims for an economical solution by enabling a high degree of automation in the mass production process.

The above-mentioned object of the present application is achieved by the solution provided in the enclosed independent claims. Advantageous implementations of the present application are further defined in the respective dependent claims. In particular, an idea of the present application is to provide a new base station antenna radiating element class which compensates the height reduction effect.

Embodiments of the present application provide an antenna device comprising at least two antenna elements, each antenna element comprising a first radiating element and a corresponding second radiating element; wherein each second radiating element extends in a height direction along a common center axis from a foot of the antenna device to its corresponding first radiating element; wherein each first radiating element extends in a length direction outwards from the common center axis; wherein each first radiating element has a greater length than its width; and wherein each first radiating element is electrically coupled to its corresponding second radiating element along the length direction.

The antenna device maintains ultra broad band characteristics, particularly a relative bandwidth greater than 30%, and reduces the overall height (with respect to the ground plane) to be lower than 0.15 λmax. The largest dimension of the first radiating element defines the maximum wavelength relating to the lowest frequency. The second radiating element of the antenna device contributes to the smaller wavelengths. This enables the radiating element to support the wished bandwidth.

In a first implementation form of the antenna device according to the present application, each of the first radiating elements has a length which is at least two times greater than its width.

In a second implementation form of the antenna device according to the present application as such or according to the first implementation form of the present application, each of the second radiating elements is planar.

That means, the second radiating element can be manufactured by processing a planar metal sheet.

In a third implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, each of the first radiating elements comprises a strip portion which extends outwards from the common center axis in the length direction and at least one bent portion which extends in an angle φ to the length direction, wherein $10° \leq \varphi \leq 170°$. It is advantageous to manufacture the first radiating element and the second radiating element out of one metallic sheet without the need for soldering, and thus enable a high degree of automation in the mass production process.

In a fourth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, for each second radiating element a length of the second radiating element is smaller at the foot as the length at its corresponding first radiating element.

In a fifth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, each second radiating element comprises a first edge extending from the foot at least partially along the height direction to a first end of the second radiating element, the first end being arranged comparatively close to the common center axis and being coupled to the corresponding first radiating element wherein each second radiating element comprises a second edge extending from the foot to a second end of the second radiating element, the second end being arranged comparatively distant from the common center axis and being coupled to the corresponding first radiating element. Thereby, the second radiating elements can contribute to the smaller wavelengths.

In a sixth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, each first radiating element of the antenna element comprises a bending edge extending in the length direction and electrically connecting the first radiating element of the antenna element to the corresponding second radiating element of the antenna element.

By using bending edges between the first radiating elements and their corresponding second radiating elements, each antenna element can be built based on a single piece, e.g. by using bent metal sheet technology. Hence, there is no need for soldering the first and second radiating elements together as they are already connected to each other by the bending edge between them.

In a seventh implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, each second radiating element comprises an opening extending in the length direction from a first connection point between the second radiating element and the corresponding first radiating element to a second connection point between the second radiating element and the corresponding first radiating element; wherein an area of the opening is as at least as large as an area of a portion of the first radiating element, the portion extending in the length direction from the first connection point to the second connection point and in a width direction from the bending edge to an edge of the corresponding first radiating element. By designing the opening in the second radiating element according to this definition, it can be achieved that the first radiating element can be bended out of the second radiating element.

In an eighth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, each antenna element comprises an impedance transformer arranged at a connection point electrically coupling the first radiating element of the antenna element to the corresponding second radiating element of the antenna element. Accordingly, the impedance transformer is integrated into the antenna element and also helps to reach the required bandwidth.

In a ninth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, each antenna element is formed in a single piece. Thereby, a high degree of flexibility of the use and the arrangement of the antenna elements can be achieved.

In a tenth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, the antenna device further comprises an electrically conducting director element being arranged in the height direction above the first radiating elements and being supported by dielectric material arranged between the director element and the first radiating elements.

The director element can compensate the capacity to ground effect caused by the height reduction and in this way the director can also contribute to the broadband matching. The director element is not directly connected to ground. This is advantageous, since it introduces also an inductive component and the bandwidth performance of the radiating element can thus be significantly improved.

In an eleventh implementation form of the antenna device according to the tenth implementation form of the present application, the director element comprises per first radiating element of the antenna element a corresponding arm extending from the common center axis outwards in the same direction as the corresponding first radiating element.

In a twelfth implementation form of the antenna device according to the present application as such or according to any one of the preceding implementation forms of the present application, the two antenna elements form a first pair of antenna elements and a dipole of the antenna.

In a thirteenth implementation form of the antenna device according to the twelfth implementation form of the present application, the antenna device further comprises a second pair of antenna elements arranged around the common center axis and forming a second dipole of the antenna device.

In a fourteenth implementation form of the antenna device according the thirteenth implementation form of the present application, the pairs of said antenna elements are arranged such that the second radiation elements of a respective pair form a 180° angle and the second radiation elements of two different pairs form a 90° angle. The antenna device is thus composed by two dipoles which are orthogonally placed, with respect to their geometrical and\or phase center, and form a 90 degree angle. In this way they form a "cross-like" structure which supports the excitation of two orthogonal E-field polarizations. This achieves a bandwidth performance with VSWR<1.35 where the relative bandwidth is greater than 35%.

BRIEF DESCRIPTION OF DRAWINGS

The main aspect and implementation forms of the present application will be explained in the following description of specific embodiments in relation to the enclosed drawings, in which

FIG. **1** shows a schematical view of an antenna device according to an embodiment of the present application.

FIG. **2** shows a schematical view the antenna device according to an embodiment of the present application.

FIG. **3** shows a top view of the antenna device according to an embodiment of the present application.

FIG. **4** shows a perspective view of the antenna device according to an embodiment of the present application.

FIG. **5** shows a top view of an antenna device according to an embodiment of the present application comprising an impedance transformer.

FIG. **6** shows the arrangement of the dielectric material.

FIG. **7** shows another arrangement of the dielectric material.

FIG. **8** shows a perspective view of the dipole according to an embodiment of the present application.

FIG. **9** shows the measurements of bandwidth performance.

FIG. **10** shows a perspective view of the first and the second radiating element.

FIG. **11** shows au arrangement of antenna devices according to an embodiment of the present application.

FIG. **12** shows another arrangement of antenna devices according to an embodiment of the present application.

FIG. **13** shows another arrangement of antenna devices according to an embodiment of the present application.

FIG. **14** shows another arrangement of antenna devices according to an embodiment of the present application.

FIG. **15** shows a capacitive connection between the first and the second radiating elements according to an embodiment of the present application.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. **1** shows an antenna device **100** for a base station according to an embodiment of the present application. The antenna device **100** comprises at least two antenna elements **105** and **106** each of which comprises a first radiating element **110** and a corresponding second radiating element **120**. The second radiating element **120** extends in a height direction along a common center axis A from a foot **103** of the antenna device **100** to its corresponding first radiating element **110**. The first radiating element **110** and the second radiating element **120** are preferably made of a (single) metal sheet.

The first radiating element **110** extends in a length direction LD outwards from the common center axis A. The length L of the first radiating element **110** defines the maximum supported wavelength. Furthermore, each first radiating element **110** has a greater length L than its width W (FIG. **3**) and each first radiating element **110** is electrically coupled to its corresponding second radiating element **120** along the length direction LD, so that the second radiating element **120** can contribute to the smaller wavelengths.

The major contribution of embodiments of the present application is to reduce the low-band radiating element height, and therefore the overall antenna height H of the antenna device **100** can be reduced by 20-30%, while keeping base station class performance, particularly keeping the relative bandwidth greater than 30%.

Compared to other ultra broad band antennas, the maximum distance of the radiating system to the reflector is reduced by 20-30%. An overall antenna height H below 0.15λMAX can be achieved where the λMAX is the wavelength of the lowest supported frequency.

As also illustrated in FIG. **4** which is a perspective view of the antenna device **100**, each of the second radiating elements **120** may be planar which allows manufacturing the antenna device **100** from a single metal sheet.

Preferably, the first radiating elements **110** of different antenna elements **105**, **106** respectively have the same shape and/or size. Similarly, the second radiating elements **120** of different antenna elements **105**, **106** may respectively have the same shape and/or size.

Further, each of the first radiating elements **110** may comprise a strip portion **111** which extends outwards from the common center axis in the length direction and at least one bent portion **113**, which extends in an angle φ between 10° and 170° to the length direction, at the outermost part **112** of the strip portion **111** of the first radiating elements **110**. The bent portion **113** may be built by using bent metal sheet technique.

Preferably, a length L**2** of the second radiating element **120** at the foot **103** is smaller as the length L**1** at its corresponding first radiating element **110**.

An edge **122** along the height direction H of the second radiating element **120** is arranged to be very close to the common center axis A. The first upper end **123** of the edge **122** is coupled to the corresponding first radiating element **110**. Another edge **124** of the second radiating element **120** extends from the foot **103** to a second upper end **125** of the second radiating element **120**. As shown in FIG. **1**, the second upper end **125** of the second radiating element **120** is coupled to the corresponding first radiating element **110**, and comparing with the first upper end **123**, the second upper end **125** of the second radiating element **120** is arranged distant from the common center axis A.

FIG. **2** shows a bending edge **114** of each first radiating element **110**. The bending edge **114** extends in the length direction LD and electrically connects the first radiating element **110** of the antenna element to the corresponding second radiating element **120** of the antenna element.

The second radiating element **120** and the corresponding first radiating element **110** can be made out of a single metal sheet by cutting a U-shaped incision **126** in the upper part **127** of the second radiating element **120**. The metal sheet formed the second radiating element **120** and the corresponding first radiating element **110** is bent along a bending edge **128** defined by two upper end points **129** of the U-shaped incision **126** in the second radiating element **120**. As more clearly illustrated in FIG. **4** which is a perspective view of the antenna device, after the bending, the portion **126'** above U-shaped incision **126** forms a part of the strip portion **111** of the corresponding first radiating element **110**, and the second radiating element **120** comprises now an opening **121** in place defined by the U-shaped incision **126** and the bending edge **128**. Thus, as illustrated in FIGS. **2** and **4**, the first radiating element **110** and the second radiating element **120** of each antenna element can be formed in a single piece.

The opening **121** is arranged between the first and the second upper ends **123** and **125** of the second radiating element **120** and extends in the length direction LD from a first connection point **171** between the second radiating element **120** and the corresponding first radiating element **110** to a second connection point **172** between the second radiating element **120** and the corresponding first radiating element **110**.

The area of the opening **121** is as large as an area of the portion **126'** of the first radiating element **110** which corresponds to the U-shaped incision **126**. Furthermore, the area of the opening **121** is larger than an area of the portion of the stripe portion of the first radiating element **110** from the first connection point **171** to the second connection point **172** and in a width direction from the bending edge **128** to the edge **114** corresponding to the U-shaped incision **126**. Furthermore, an edge **115** opposite to the edge **114** forms another bending edge **115** of the first radiating element **110**. Along this other bending edge **115** a further strip portion **115'** of the first radiating element **110** extends along the length direction of the first radiating element **110** in this example in a 90° angle to the strip portion **111**. According to further embodiments the angle between the further strip portion **115'** and the strip portion **111** can be in a range >=10° and <=170°.

An important advantage is that the antenna elements can be built using bent metal sheet technology. This allows realizing the second radiating element **120** and the corresponding first radiating element **110** out of one single metallic sheet (without the need for soldering). Embodiments of the present application thus enable a highly degree of automation in the mass production process with all the advantages of the case.

Preferably, each of the second radiating elements **120** may have a substantial triangular portion **173** between its foot and its upper ends (cf. FIG. **1**).

As shown in FIG. **4**, a pair of antenna elements **105** and **106** forms a dipole of the antenna and two pairs of antenna elements **105**, **106**, **107** and **108** arranged around the common center axis. The two pairs of said antenna elements **105**, **106**, **107** and **108** are arranged such that the second radiation elements of a respective pair form a 180° angle and the second radiation elements of two different pairs form a 90° angle. That is to say, preferably, the two pairs of dipoles **105**, **106**, **107** and **108** are orthogonally or quasi-orthogonally arranged.

This allows to the dipole structure itself to maintain ultra broad band characteristics even reducing the overall height which respect to the ground plane<0.15 λmax. Indeed, the first radiating element **110**, namely the largest dipole arm dimension, defines the maximum wavelength. The galvanically and/or capacitively connected second radiating element **120** gradually contributes to the smaller wavelengths. This enables the radiating elements **110** and **120** to support the wished bandwidth.

As shown in FIGS. **2**, **3** and **4**, a director element system comprising one or more director elements **140** (e.g. Disk, cross, cylinders, ring etc.) is placed on the antenna elements (dipoles) **105**, **106**, **107** and **108**. The function of the director element system is to compensate the capacity to ground effect generated by the height reduction and in this way contributing to the broadband matching.

The director element system is not directly connected to ground. This has the advantage to introduce also an inductive component and by this way has the clear advantage to significantly improving the radiating element bandwidth.

As illustrated in FIG. **5**, an impedance transformer **130** is integrated in the first radiating element **110** around the feed point **116**. Each antenna element comprises an impedance transformer **130** arranged at the connection point **171** electrically coupling the first radiating element **110** of the antenna element to the corresponding second radiating element **120** of the antenna element.

It also can be seen from FIG. **5** that the length L of each of the first radiating elements **110** can be at least two times greater than the width W the first radiating elements **110**.

The electrically conducting director element **140** is arranged in the height direction H above the first radiating elements **110** and being supported by dielectric material **150** arranged between the director element **140** and the first radiating elements **110**. As shown in FIGS. **6** and **7**, the additional dielectric material **150** is preferably placed e.g. between the 2 directors **140** and/or the directors **140** and the dipoles **105**, **106**, **107** and **108**, and can be used for timing the bandwidth and as mechanical support for the antenna device **100**.

The director element **140** comprises per first radiating element **110** of the antenna element a corresponding arm **141** extending from the common center axis outwards in the same direction as the corresponding first radiating element **110**. Furthermore, at least in some examples, the director system is composed of 2 quasi elliptical orthogonal crosses as shown in FIG. **3**.

FIG. **8** shows a perspective view of the arrangement of the dipoles according to an embodiment of the present application.

Specially, a realization example of a dual polarized antenna device (e.g. a low band radiator) is shown in FIGS. **2** to **8**. The antenna device is composed by 2 pairs of radiating elements, each pair forming a dipole, placed 90 degree orthogonal regarding the geometrical center (the common center axis A). The two dipoles form a "cross-like" structure which supports the excitation of 2 orthogonal E-field polarizations. In this realization example, a bandwidth performance (VSWR<1.35 @ relative bandwidth>35%) can be achieved. The second radiating elements **120** (dipole feet) are electrically connected to the first radiating elements **110** (the dipole arms). The mechanical and electrical material properties of the mounting system for the director **140** and the crosses formed by the dipoles shown in FIGS. **4** and **8** are chosen to optimize the bandwidth and stability performance.

In FIG. **9**, it is shown by measurements that required bandwidth performance can be meet when even when reducing the height<40%.

FIG. **10** shows another embodiment of an antenna device **200**. Accordingly, two antenna elements **205** and **206**, each of which comprises a first radiating element **210** and a second radiating element **220**, are arranged such that the second radiating elements of the two antenna elements form a 90° angle.

FIG. **11** shows an arrangement of several antenna devices **100**. Accordingly, at least two antenna devices **100** are placed in a line along the length direction LD of the antenna device, and form a line of the antenna device array **300**. Preferably, the lines defined by the length direction LD of the antenna device arrays **300** are arranged parallel to each other in a plane.

FIG. **12** shows a further arrangement of several antenna devices **100**. Accordingly, at least two antenna devices **100** are placed parallel to each other and form an antenna device group **401**. Preferably, at least two such antenna device groups **401** and **402** are arranged, so that a length direction LD**1** of the antenna device in a first antenna device group **401** is perpendicular to a length direction LD**2** of the antenna device in a second antenna device group **402**.

FIG. **13** shows a further arrangement of several antenna devices **100**. Accordingly, at least four antenna devices **100** form a rectangular antenna device group and each first radiating element **110** is arranged to be perpendicular to two neighboring first radiating elements, so that the first radiating elements **110** of the at least four antenna devices can form the rectangular antenna device group **500**.

FIG. **14** shows an arrangement of several antenna devices **200** according to FIG. **10**. Specially, at least four antenna devices **200** form a rectangular antenna device group **600**. Each antenna devices **200** forms a right angle **601** of the rectangular antenna device group **600**. Preferably, each first radiating element **110** of the four antenna devices **200** is arranged such that the outer end of the each first radiating element **110** faces and is close to the outer end of a first radiating element **110** of a neighboring antenna device **200**.

The proportions between the height H from a reflector to the dipole feet and the length L of dipole anus (the first radiating element **110**) are typically 1:4.

FIG. **15** shows a possible capacitive coupling **180** between the first radiating element and **110** the second radiating element **120** by using any suitable fastening means. e.g. clip, latch, hook or bolt fastening.

The present application has been described in conjunction with various embodiments as examples as well as implementations. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed application, from the studies of the drawings, this disclosure and the independent claims. In the claims as well as in the description the word "comprising" does not exclude other elements or steps and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

The invention claimed is:

1. An antenna device comprising:

at least two antenna elements, each antenna element comprising a first radiating element and a corresponding second radiating element;

wherein:

each second radiating element extends in a height direction along a common center axis from a foot of the antenna device to its corresponding first radiating element;

each first radiating element extends in a length direction outwards from the common center axis;

each first radiating element has a length greater than its width;

each first radiating element is electrically coupled to its corresponding second radiating element along the length direction; and

for each second radiating element a length of the second radiating element is smaller at the foot as the length at its corresponding first radiating element.

2. The antenna device according to claim **1**,

wherein the length of each of the first radiating elements is at least two times greater than its width.

3. The antenna device according to claim **1**,

wherein each of the second radiating elements is planar.

4. The antenna device according to claim **1**,

wherein each of the first radiating elements comprises a strip portion which extends outwards from the common center axis in the length direction and at least one bent portion which extends in an angle φ to the length direction, wherein $10° \leq \varphi \leq 170°$.

5. The antenna device according to claim **1**,

wherein:

each second radiating element comprises a first edge extending from the foot at least partially along the height direction to a first end of the second radiating element, the first end being arranged comparatively close to the common center axis and being coupled to the corresponding first radiating element; and

each second radiating element comprises a second edge extending from the foot to a second end of the second radiating element, the second end being arranged comparatively distant from the common center axis and being coupled to the corresponding first radiating element.

6. The antenna device according to claim **1**,

wherein each first radiating element of the antenna element comprises a bending edge extending in the length direction and electrically connecting the first radiating element of the antenna element to the corresponding second radiating element of the antenna element.

7. The antenna device according to claim **6**,

wherein:

each second radiating element comprises an opening extending in the length direction from a first connection point between the second radiating element and the corresponding first radiating element to a second connection point between the second radiating element and the corresponding first radiating element; and

an area of the opening is as at least as large as an area of a portion of the first radiating element, the portion extending in the length direction from the first connection point to the second connection point and in a width direction from the bending edge to an edge of the corresponding first radiating element.

8. The antenna device according to claim **1**,

wherein each antenna element comprises an impedance transformer arranged at a connection point electrically coupling the first radiating element of the antenna element to the corresponding second radiating element of the antenna element.

9. The antenna device according to claim **1**,

wherein each antenna element is formed in a single piece.

10. The antenna device according to claim **1**, further comprising:

an electrically conducting director element being arranged in the height direction above the first radiating elements and being supported by dielectric material arranged between the director element and the first radiating elements.

11. The antenna device according to claim **10**,

wherein the director element comprises per first radiating element of the antenna element a corresponding arm extending from the common center axis outwards in the same direction as the corresponding first radiating element.

12. The antenna device according to claim **1**,

wherein the two antenna elements form a first pair of antenna elements and a dipole of the antenna device.

13. The antenna device according to claim **12**, further comprising a second pair of antenna elements arranged around the common center axis and forming a second dipole of the antenna device.

14. The antenna device according to claim **13**,

wherein the pairs of said antenna elements are arranged such that the second radiation elements of a respective pair form a 180° angle and the second radiation elements of two different pairs form a 90° angle.

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